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<b>(54) Title:</b> MICRO-ELECTRO-MECHANICAL INTEGRATED CONTROL SYSTEMS		
<b>(57) Abstract</b> <p>An integrated electro-mechanical control device has an interface for communicating with a central computer system, or an array of computer systems, to allow for the distributed and reconfigurable development of a control network. The control units described herein can include a plurality of microelectronic devices including micromachined sensors such as pressure sensors and temperature sensors which are formed on a chip including a circuit for being able to selectively configure the various sensor elements under the control of a central computing system.</p>		

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## MICRO-ELECTRO-MECHANICAL INTEGRATED CONTROL SYSTEMS

### Related Application

5           This case claims priority to USSN 60/054,951 entitled Micro-Electro Mechanical Integrated Control System, filed 7 August 1998.

### Field of the Invention

10           The invention relates to control systems and more particularly to control systems capable of monitoring the operating state of a process or system.

### Background of the Invention

15           Today, a number of companies develop and sell control systems for monitoring and controlling complex systems, such as chemical plants, assembly lines, and transportation networks. These control systems rely on sophisticated data processing devices that connect to a plurality of sensors and instruments that are coupled into the system being monitored at locations that yield useful information about the operating state of the system. Accordingly, a typical control system will employ a centralized data  
20           processor that is in communication with a plurality of different sensors, such as pressure sensors, tachometers, and temperature sensors. Each sensor is positioned to collect information about the system or process under control that allows the data processor to regulate the process and achieve a desired operating condition.

25           Although these control systems can work well, they can be quite complex and expensive. One source of complexity and expense is the interface between the data processing systems and the different sensors and instruments connected into the system being monitored. Commonly, each type of sensor, such as a thermometer or a tachometer, has a proprietary or customized interface that must connect to the data  
30           processor. The interface can sometimes include a software device driver that has been

custom written for each sensor and instrument in the control system. Accordingly, the control system must be custom adapted to operate these different sensors. Additionally, each type of sensor or instrument can have a different type of hardware interface, such as a parallel, serial, or bus interface. This requires a customized interface hardware for  
5 coupling the sensors to the data processing equipment.

Consequently, there is a need for a control system in which a data processor can be easily and efficiently integrated with the sensors and instruments coupled to the system being controlled.

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Moreover, control systems and closed-loop control systems have been developed for large-scale mechanical, electromechanical or processing systems. With the advent of micro-mechanics and subsequently "mechatronics", the coalescence of micro-mechanics and micro-electronics, there is a need for control systems at the scale of these devices.

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### Summary of the Invention

The systems and methods of the invention include integrated control instruments that can be directly coupled to the sensors, motors, valves, or other device used in a  
20 controlled system. These micro-electro-mechanical integrated control systems (MEMICS) provide an architecture for open or closed loop control of systems and devices including micro systems for micro-electronic, micro-mechanic or micro-chemical processing. The devices contain components and processes that allow control supervision by a computer or by an operator (open loop) of multiple micro-systems and  
25 of micro-sensors. Moreover, each integrated control unit can control or monitor a plurality of control devices and sensors and provide a standardized interface for the plural devices to the data processing system. This allows for the achievement of efficiencies in the transfer of data and instructions between the data processing system and the control devices and sensors.

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More particularly, the invention is understood to include apparatus for controlling a system, comprising a data interface for communicating data packages representative of data and command signals across a data network, a communications manager coupled to the data interface for processing the data packages to exchange data and command  
5 signals with a data processor, wherein each data package organizes the data and command signals according to a predetermined format suitable for transfer across the data network, and a device manager adapted for processing the data and command signals to generate control signals for selectively configuring an operating characteristic of a device coupled to the system being controlled. In one embodiment, the device  
10 includes a sensor that is coupled in communication with the device manager. In another embodiment, the device includes an actuator that is coupled into communication with a device manager. In a further embodiment the device is maintained within a housing that contains the sensor, the device manager, the communications manager and the data interface. Each of these elements can be held within the housing, such that the actuator  
15 and the sensors are maintained within the housing along with the device manager and the communications interface. In one embodiment, the device further includes a multiplexed interface for allowing the device manager to monitor and control a plurality of devices coupled to the system being controlled.

20 In an optional embodiment, the system includes an encryption processor for encrypting and decrypting the data signals and command signals that are transferred across the data network. In yet a further embodiment, the apparatus can include an interface for coupling to a system monitor that allows a user to monitor and adjust the operation of the device, and can further include a system clock for maintaining a measure  
25 of time within the system.

In a further embodiment, the invention can be understood as an integrated control device for monitoring characteristics of a system under control. The integrated control device can include a housing that is adapted for being removably and replaceably  
30 mounted to, adjacent, or proximate the system under control. The housing can contain

the data interface for communicating the data packages representative of the data and command signals, the communications manager, and the device manager that is responsive to the data and command signals and capable of controlling and monitoring a sensor that monitors a characteristic of the operating state of the system under control.

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In a further embodiment, the invention can be understood as a semiconductor device for monitoring a system under control. The semiconductor device can include a substrate that has a plurality of circuits formed thereon. The circuits can include a communications manager for processing data packages having data and command signals wherein each data package organizes the data and command signals according to a predetermined format suitable for transfer across a data network. The circuits can further include a device manager adapted for processing the data and command signals to generate control signals for operating a device coupled to the system being controlled, a sensor capable of monitoring a characteristic of the system under control and an actuator capable of adjusting an operating parameter of the system under control, whereby command signals communicated from a data processor are processed by the device manager for controlling the sensor and the actuator to perform selected operations. In one embodiment the semiconductor device can include sensors that consists of tilt sensors, temperature sensors, pressure sensors, an accelerometer, a gyroscope, a light detector, a microphone, and any combination thereof including a plurality of similar sensors, such as a plurality of pressure transducers. Similarly, the semiconductor device can include actuators of a number of different types including motors, pumps, valves, data ports and I/O lines, as well as any combinations thereof including combinations that provide plurality of similar types of actuator elements, such as the plurality of different motors or pumps.

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In a further embodiment, to provide for sophisticated communication between the devices monitoring the system under control and the data processor, the integrated circuit can include a communications manager that can generate an ID signal or a field for storing an ID signal which will identify the system under control that is associated with

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that data package. Similarly, the communications manager can include a device ID generator that will generate a device ID signal suitable for identifying the device that is generating the particular data packet carrying that device ID signal. In this way, a single data processor can be operating a plurality of different processes each of which is  
5 listening for data packages associated with a particular one or set of systems under control. Further, the data processor as well as other elements of the system can identify from data packages the particular device that is generating the information representative of a characteristic of the operating state of the system under control. This is particularly helpful in those situations where each device includes an interface to a radio frequency  
10 transmission system for exchanging data signals through radio frequency signals. This can allow a transceiver in communication with the plurality of different devices to understand which of the devices is generating which set of information.

In a further aspect, the invention can be understood as control systems that  
15 monitor and adjust an operating state to the system under control. The control systems can include a data processor of the type capable of processing information representative of at least one characteristic of an operating state of the system under control, and of generating command signals representative of instructions for configuring the operating of a sensor device. The systems can further include a data network coupled to the data  
20 processor and being of the type suitable for communicating information signals, and a plurality of sensor devices wherein each is coupled to the system under control for monitoring a characteristic of the operating state of the system and wherein each sensor device includes a communications manager, a device manager and a sensor capable of monitoring characteristics of the system under control. In these systems, command  
25 signals generated by the data processor and communicated across the data network can be received by the plurality of sensor devices for configuring each of the sensor devices to operate in a certain manner. In this way, a control system can be provided wherein a plurality of generic, or similar, sensor devices are located at different locations on the system being controlled and are configured according to the needs of the data processor

to provide information representative of characteristics of the operating state of the system under control.

5 In a further aspect, the invention can be understood as a process for controlling a system having an operating state having at least one characteristic representative of the operating state. These processes can include providing a data processor of the type capable of processing information representative of at least one characteristic of the operating state of the system under control and of generating command signals representative with instructions for configuring the operation of a sensor device,  
10 providing a data network coupled to the data processor and being of the type suitable for communicating information signals and coupling a sensor device to the system under control for monitoring the characteristics of the operating system, wherein the system has a communications manager, a sensor capable of monitoring characteristics of the system, and a device manager adapted for processing data and command signals from the data  
15 processor for controlling the operation of the sensor. In a further step, these processes can transmit from the data processor command signals that will configure the sensors to operate in a selected manner. In a further embodiment of these processes, the sensor devices can further include actuator elements that are capable of adjusting or modifying an operating parameter of the system under control. For these systems, the data  
20 processor can also generate command signals that are capable of operating, or configuring, the actuator to adjust the selected parameter of the system under control.

Accordingly, the MEMICS architecture makes it possible to integrate the electronic and mechanical parts of the control system in a single instrument. The  
25 integrated control instrument can provide a battery of sensors and devices that can be configured for a selected application to monitor (micro-) electronic, (micro-) mechanic or (micro-) process machines such as sensors, motors, alarm systems, communication systems, spectrographs, aerospace devices, and medical devices. These systems provide configurable control devices that can exist at the scale of the devices being controlled,  
30 including systems as the circuit and component level.



### Brief Description of the Illustrated Embodiments

5 The figures depict certain illustrative embodiments of the invention and are not to be understood as limiting in any sense.

Fig. 1 depicts a functional block diagram of one architecture of a device according to the invention;

10 Fig. 2 depicts a control system having a plurality of devices of the type depicted in Figure 1 coupled into a system under control;

Fig. 3 depicts in block diagram form an integrated circuit device for controlling a system;

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Fig. 4 depicts a device having a housing capable of being mounted to a system being controlled; and

Fig. 5 depicts a flow chart of one process according to the invention.

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### Detailed Description of the Illustrated Embodiments

The systems and methods described herein provide integrated control devices that can operate a plurality of devices, including a plurality of sensors. For illustrative purposes, the systems and methods described herein will be generally shown as sensor systems that allow for the monitoring and controlling of a work-space, or other similar environment. However, it will be understood by one of ordinary skill in the art that the systems and methods described herein are not to be so limited and that other applications of this technology fall within the spirit and scope of the invention.

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The systems and devices described herein provide integrated electrical mechanical control systems that provide a configurable sensor and actuator device. Each configurable device can include a battery of sensors, such as thermometers, pressure gages, accelerometers, and other devices as including one or more actuators, such as pumps, valves, motors, adjustable lenses, and other devices. Each of these devices, both sensors and actuators can be controlled by a device manager that will configure the parameters under which these sensors and actuators will work. For example, the device manager can configure the temperature ranges over which a temperature sensor will operate. Similarly, the device manager can configure the operational parameters of a motor to define the rate at which the motor can turn. Further, the device manager can also enable and disable certain ones of the sensors and actuators such that in a device containing a pressure sensor, and a thermometer, only the thermometer is enabled for operation such that the sensor device is collecting solely temperature information.

To configure the operation of the sensors and actuators, the device manager can receive commands through a communications manager that is interfaced either directly, or indirectly, to a data network that can exchange data packages with a data processor coupled to the network. The data processor can generate data packages that include command signals which will be transferred through the communications manager of the integrated control instrument to the device manager. The device manager will respond to the command signals for configuring the device, such as by enabling certain ones of the sensors coupled to the device, and selecting the operating parameters for that device. In this way, the data processor can provide a central station that can configure a plurality of integrated sensor devices which are located at different locations on the system under control. Each of the sensors can monitor a certain parameter that is associated with the operating state of the system under control and can provide data packets of information through the data network to the data processor for allowing the data processor to monitor, and in some applications adjust, the operating state of the system under control. Accordingly, it will be understood that the integrated control systems described herein provide for configurable sensor and actuator systems that can be located at different

locations of a system under control and dynamically configured by a data processing system to allow the data processing system to implement a control system for monitoring and adjusting the operating state of the system under control.

5           The systems described herein can couple to or incorporate a wide range of disparate sensor types, each of which can operate differently. To facilitate the use of these disparate devices, a device manager is provided which can couple to an input/output interface device. Each of the sensors coupled to the system, can be connected to the interface, such as, for example, by being coupled in electrical circuit to the interface. The device manager can operate the input/output device to initialize, 10           disable, monitor and control the sensors. The device manager can then encapsulate the information collected by the sensors into common format, and the encapsulated data can be sent to a central processing facility that reads the data and effects control changes as appropriate.

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Fig. 1 depicts one example of an integrated electronic and mechanical sensor control device. To that end, the depicted system 10 includes a command and control computer 12 that couples to a transceiver 14, which in turn communicates with the MEMIC device 16. The MEMIC device 16 can work as a stand-alone device or in a many-to-many configuration, wherein a plurality of MEMICS can interact with many 20           command and control units. This allows back-up and enhanced availability. Fig. 1 further depicts, a plurality of devices 40, a system monitor 44, an open loop feedback device 42, and open loop interrupt device 46, a system clock 50, a power manager 52, and a power supply 54. The MEMICS 16 of Fig. 1 is shown in functional block diagram form and includes a transceiver 20, a communication manager 22, an encoder/decoder 26, 25           an encryptor/decryptor 28, a device manager 24, a device monitor 30, DAC/ADC devices 32 and a device I/O manager 34.

30           The command and control computer 12 depicted in Fig. 1 is a data processing system of the type commonly employed for running a computer program that implements

a monitor and control process, and for example can be a stand alone controller system, such as the type sold by the Foxboro Company of Foxboro, Massachusetts, or can be a conventional computer work station, such as an IBM PC compatible work station that is running a computer program to configure it to operate as a data processor control  
5 system.

The command and control computer 12 can run under the control of a computer program that is capable of directing the command and control computer 12 to generate command signals that are representative of signals for initializing, enabling and  
10 configuring the devices 40 depicted in Fig. 1. The command signals can include instructions for enabling or disabling an interface to a device 40. The command signals can further include instructions for setting the operating ranges, such as temperature ranges, pressure ranges, and other parameters that are employed for setting up the devices 40. The computer program running on the command and control computer 12  
15 can be a conventional computer program such as a C language program or a JAVA language program that can download applets from the command and control computer 12 to the integrated control unit 16 for providing client side control of the initialization and operation of devices 40.

20 The Fig. 1 further depicts a transceiver 14 that couples to the command and control computer 12. The transceiver 14 can be a network interface card that takes command signals and data signals generated by the command and control computer 12 and formats them in a format suitable for delivery over the physical layer of a computer network, such as an ethernet network, or any IP network. Alternatively, the transceiver  
25 14 can be a network interface card that is connected through a data network to the command and control computer 12 for receiving data packets, such as IP data packets carried on a computer data network which provides a bidirectional data path between the transceiver 14 and the command and control computer 12. The transceiver 14 can receive the data packets from the computer network and translate these data packages  
30 into signals that can be broadcast to the integrated control unit 16. For example, the

transceiver 14 can include a network interface card that couples to the data network in communication with the command and control computer 12. The network interface card of transceiver 14 can couple to a radio frequency transceiver that will broadcast data and command signals to the transceiver 20 of the integrated control unit 16. In this way, the  
5 integrated control unit 16 can be physically separated from the computer network without requiring a connection to the network cable. Although the above transceiver 14 has been described with reference to a radio frequency link, it will be understood by one of ordinary skill in the art that infra red links, twisted pair links, or any other suitable communication link between the transceiver 14 and the integrated control unit 16.

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The depicted transceiver 14 is attached to the I/O bus of the command and control computer 12, through communication, parallel or PC-Card ports. The transceiver unit receives power from the computer. An operator can take control away from the main program and interrupt the device control system. The operator can interact with a  
15 system monitor that can include a keypad, switch, video display or other suitable I/O device or devices.

The integrated control unit 16 includes a transceiver 20 for exchanging data and command signals with the transceiver 14. The transceiver 20 can be any conventional  
20 transceiver element, including a radio frequency, or infra red transceiver unit and will be selected to be compatible with the transceiver 14 that is in communication with the command and control unit 12. Accordingly, each device 16 can have a transceiver through which it communicates with the transceiver of the command and control system. The depicted transceivers allow the device to operate in wireless mode, whether in radio  
25 frequency, infra red or otherwise. To that end they are equipped with the necessary electronics and logic for telecommunication including antennas or electro-optical or ultrasound or any other means. The transceiver contains means to perform error detection/error correction and all necessary facilities to ensure proper data transfer.

The transceivers and may be replaced with electrical or optical wire, on condition that the communication signal is properly managed. The communication manager is responsible for preparation and acceptance of the messages for transmission. It has two main modules: an encoder/decoder unit that organizes the data in the message, and an  
5 encryptor/decryptor unit that ensures that messages are only exchanged with authorized command/control computers or are exchanged in a format that can only be understood or processed by authorized or selected processors.

As further shown by Fig. 1, the transceiver 20 is in bidirectional communication  
10 with the communications manager 22. The communications manager 22 includes an encoder/decoder element 26 and an encrypter/decrypter unit 28. As further shown by Fig. 1, both the encoder unit 26 and encrypter unit 28 are coupled in bidirectional communication. As further shown by Fig. 1, the communication manager 22 is coupled between the transceiver 20 and the device manager 24. The communications manager  
15 can be an electronic circuit, or a software program running on a general purpose microprocessor. The communication manager 22 employs the encoder/decoder unit 26 to organize the data in the data packet for transmission through transceiver 20 to transceiver 14. The data is organized by encoder 26 into a format that will be understood by the computer program operating on the command and control computer 12. Similarly,  
20 the encoder/decoder 26 can receive data packets generated by the command and control computer 12 and select from these data packets the command and data signals that are to be sent to the device manager 24 for initializing and configuring the operation of sensors 40. Data transferred from the encoder 26 through transceiver 22 and to transceiver 14 can, in one embodiment, be formatted by a network interface card that is part of  
25 transceiver 14 into a format that is suitable for transmission across the data network that carries data between the transceiver 14 and the command and control computer 12.

Fig. 1 further depicts an optional element, the encrypter/decrypter 28. The encrypter/decrypter 28 can be an electrical circuit or alternatively, can be a software  
30 routine running on a conventional microprocessor. The encrypter/decrypter can operate

to encrypt and decrypt signals to provide a layer of security for the communications between the integrated control unit 16 and the command and control computer 12. This reduces the likelihood of tampering that could interfere with the proper monitoring of the system under control.

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Fig. 1 further depicts a device manager 24 that includes a device monitor 30 that couples through the digital analog converter 32 and to the device I/O multiplexer 34. The device manager 30 transfers data between the devices 40 and the communications manager 22. Additionally, the device manager 24, which can be an electrical circuit, or a software routine running on a microprocessor, processes and responds to the command and data signals provided from the command and control computer for configuring, enabling, and operating the devices 40. Specifically, the device manager 30 can include a state machine that responds to the command signals to selectively enable, and disable the devices 40. For example, in one embodiment, the command and control computer 12 can transfer a command signal to the device manager 24 that directs the device manager 24 to enable one of the devices 40, wherein that enabled device 40 consists of a pressure sensor. Additionally, the control computer 12 can set command and data signals that direct the device manager 30 to set the operating parameters of the enabled pressure sensor 40. For example, certain pressure sensors can be operated within selected ranges by selecting a reference voltage that is applied to the pressure sensor.

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In this embodiment, the device manager 30 will respond to commands from command and control computer 12 to select the proper reference voltage to achieve the desired pressure sensing range. It will be understood by one of ordinary skill in the art, that the device manager 30 can set any of the parameters necessary for the devices 40 and that the design and development of such device managers is well known to those of ordinary skill in the art of electrical engineering. The device monitor 30 can also receive data from the sensors, such as pressures measured by the sensors 40. A device manager 30 can pass these signals through to the communications manager 22 for encapsulation and delivery to the transceiver 14. The digital to analog converter and analog to digital

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converter 32 depicted in Fig. 1 can be any suitable circuit system for performing these functions and can be separate integrated circuit components or integrated circuit components provided as part of a single integrated circuit. However, it will be understood that modifications can be made to the signal conditioning circuitry employed by the devices described herein as necessary, and such modifications are deemed to be within the skill of one of ordinary skill in the art of electrical engineering.

In the depicted embodiment, a plurality of devices 40 coupled by a bidirectional path to the device manager 24. To this end the device manager 24 includes a device I/Omultiplexer 34. The device I/Omultiplexer can be an electrical circuit or a software routine running on a conventional microprocessor. The operation of such multiplexers for switching between individual ones of the devices 40 for transferring data between the selected device and the device manager 24 are well known in the art and any suitable multiplexer can be employed with the present invention.

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The integrated control device 16 depicted in Fig. 1 includes a bidirectional interface to a system monitor 44. The system monitor 44 can be a visual display such as a computer terminal with a keyboard that allows an operator to interface with the integrated control instrument, for example, changing parameters of the sensor devices 40, as well as for monitoring data generated by the sensor devices 40. A system monitor 44 couples to an open loop feedback device 42. These open loop feedback devices 42 can be, for example, alarms, such as sirens or flashing lights, that are activated by the integrated control unit 16 when certain data from one of the devices 40 indicates an alarm condition. The depicted system monitor 44 also connects to an interrupt device 46. The interrupt devices 46 allow an operator to override the command signals being implemented by the device manager 24. Accordingly, the interrupt devices allow for disabling selected devices 40, or enabling other devices 40, or for allowing a user to send information through the integrated control instrument 16 to the command and control computer 12. In other applications for the interrupt devices 46 can be employed with the systems described herein without departing from the scope of the invention.

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Fig. 1 further shows that the integrated control unit 16 can couple to a system clock 50 and a power management and power supply unit 52 and 54. The system clock can be a conventional electronic clock element that provides a clock signal to the device manager 30. Such clock signals can be employed for timing the rate of changes of certain parameters such as pressures and temperatures as well as for monitoring and maintaining information about the status of the integrated control unit 16, such as how long the control unit 16 has been operating and on what day and time data was collected to be transferred back to the command and control computer 12. The system clock allows the synchronization of all the signals processed in the control unit 16. An optional power management unit is responsible for energy conservation and allocation over the various devices in function of the needs indicated by the system monitor. The power management and power supply units 52 and 54 can be conventional battery or A/C power supplies. Although the system clock 50 and power management and power supply systems 52 and 54 are depicted by Fig. 1 as being separate components of the system 10, it will be understood by one of ordinary skill in the art that these components can be incorporated into the integrated control device 16.

The main program of a closed-loop system runs in the computer 12 or array of computers. The program has a user interface for interaction with an operator and performs the principal data analysis and command and control functions. The program can optionally include an encryption program. The program can provide for real-time operation by providing command signals with priority values that will be understood by the device managers 30 for determining the order of which operations occur. This allows the computer to determine which sensor data is reported back first, and which actuator is activated first, or in any other order.

As discussed, the device manager transfers the messages from/to the devices that are being controlled. It contains a device monitor responsible for the digital processing of the signals, equipped with the necessary logical and arithmetic functions, and with the necessary memory to assure throughput. The depicted device manager contains a digital-

to-analog converter and an analog-to-digital converter. It also contains a device input/output channel multiplexor, that allows the device monitor to switch its attention from one device to another.

5           Although Fig. 1 depicts a single control unit 16, multiple (micro) electro-mechanical devices can be interfaced to the integrated control instrument of the MEMICS. They can be sensors, motors, process devices. The integrated control device is supervised by a system monitor. The system monitor is responsible for the general functioning of the ICI. It exchanges status information with the command and control  
10 computer or with the operator via open loop feedback devices such as light emitting diodes. It reacts on the command signals received from the command and control unit or from the operator via interrupt devices such as switches or buttons. In this way, an operator can override the command system, shutdown the sensor or device, run separate tests off-line, or other similar function.

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Figure 2 depicts a system 10 according that includes a plurality of transceiver elements 16a-16f coupled to a network bus 15 that is connected to a command and control computer 12. As discussed above the command and control computer 12 performs the processing for the control system and responds to operator input. Figure 2  
20 further depicts a room 30 that includes the transceiver 16d and four integrated control units 18a-18d of the type described above with reference to Fig. 1. The room 30 can contain an assembly line, chemical plant, a working environment or any system or space that is to be monitored or controlled. The integrated control units 18a-18d each couple to a sensor or device. For example, the unit 18a couples to a valve 20 that has a motorized  
25 shutoff assembly. Similarly, the units 18a and 18b couple to thermostats 22 and 24 respectively. The unit 18d couples to a generic sensor/device element representative of any element suitable for use in a control system.

As described above, the units 18a-18d can receive commands and provide data to  
30 the transceiver 16d via a data link such as an IR or radio link. Optionally, a hardwired

link can be employed. The transceiver 16d, in the depicted embodiment, exchanges data and instructions with the command computer 12 via the network 15.

Each unit 18a-18d can receive command data signals from the command  
5 computer 12. This data can instruct the device manager 24 on how to drive, or interface with the sensor, actuator or other device coupled to that unit. The device manager 24 can use this information to collect information from the sensor actuator and devices and can translate this information into a standard data format that can be sent to the  
10 transceiver 16d. The transceiver 16d can format the data into a standard format suitable for delivery over the network 14. Accordingly, the system 10 provides a control system with a standard interface to its devices, actuators and sensors.

Figure 3 depicts an alternative embodiment in the invention wherein the integrated control device is formed as an integrated circuit such that on a substrate the circuits and  
15 sensors of a device according to the invention are formed. Specifically, Figure 3 depicts an integrated circuit 60 that includes a microprocessor core 62, a static RAM 64, and electrically programmable memory 66 and a read-only memory 68. The device 60 further includes a gyroscope 70, a temperature sensor 72, a gyroscope 74, and an accelerometer 76. The microprocessor core 62 can be a conventional microprocessor core that operates  
20 in response to a computer program stored in the ROM 68 and the EEPROM 66. The microprocessor core 62 can also act in response to input signals received from an IO interface (not shown) of the type commonly employed with microcontroller circuits.

Figure 3 depicts that the integrated control device can be formed on a substrate  
25 wherein a programmable microprocessor core 62 operates under the control of a program to implement the communications manager, and device manager functions of the integrated control device. In one embodiment, the microprocessor core 62 is similar to the 68HC05 core developed by the Motorola Company, which can be programmed in a high-level language, such as C, to generate a set of instruction signals that can implement  
30 the communications manager and device manager functions. The development of such

programs follows from principals well-known in the art of electrical engineering and computer science and any suitable computer program can be employed with the present invention without departing from the scope thereof. The integrated system 60 depicted in Figure 3 also includes four sensor elements which can be individually configured by the microprocessor circuit to operate to collect selected information about the system under control. For example, in one embodiment the microintegrated control device 60 can be attached to a box moving on a conveyor belt. In this embodiment, the microprocessor can employ the accelerometer 76 and gyroscope 74 to receive directional and movement information for use by the control program running on the command and control computer 12. In an alternate portion of the control system, the device 60 can be placed at a location on the system under control where measures of temperature are relevant to maintaining an optimal operating state, and this application the command and control program can send a program to the microcontrol unit 60 that executes from the EEPROM 66 to direct the microprocessor core to activate the temperature sensor 72 and to report back temperature data gathered from that sensor. To report back data, the element 60 can be coupled to an infrared transceiver element (not shown) that acts to exchange data between the transceiver 14 that couples to the computer data network which will transmit information between the transceiver 14 and the command and control computer 12.

Figure 4 depicts in functional block diagram form a further alternative embodiment of the invention. Specifically, Figure 4 depicts a system 90 that includes a housing 90 tube which can be mounted to a portion of the system being controlled. The system 90 can include a microcontroller 90 for, a transceiver 98, and sensors 102, 104 and 106. In the depicted embodiment the sensors 102, 104 and 106 are a pressure sensor, temperature sensor and accelerometer respectively. These three sensors can operate under the control of the microcontroller 94 for measuring certain parameters of the system under control. In an alternate embodiment, the system 90 can include an IO port for forming an electrical connection to a sensor, or actuator that is physically separated from the housing 90. In this way the integrated control device 90 can also

communicate with devices that are separate from the unit, but coupled to the system being controlled.

5       The transceiver 98 depicted in Figure 4 can be employed for transmitting signals to a transceiver that is in communication with the data network and carries data to the central computer system. In one embodiment, a plurality of devices, such as the device 90 could communicate to a single transceiver 14. In this embodiment, the communications manager can generate a device ID representative of a unique one of the devices 90 that is communicating with the transceiver 14. This allows the transceiver 14  
10       to determine which device is speaking to the transceiver 14, and accordingly provides the transceiver 14 with information to use for transferring data over the computer data network.

15       Figure 5 depicts one process according to the invention for controlling and monitoring a system. Specifically, Figure 5 depicts a process 120 that includes the steps of generating initialization and data commands 122 broadcasting data and commands 124, verifying the initialization of integrated control units 126, monitoring data 128, determining if the monitoring system needs reconfiguration 130 and generating the necessary reconfiguration command and data signals 132.

20       Specifically, the process 120 depicted in Figure 5 can be employed by the command and control computer 12 to initialize and reconfigure the sensor units employed for monitoring the system under control. In the first step 122 the command and control computer can initialize the configuration of the system under control. In this step, the  
25       command and control computer 12 generates a set of configuration information that is employed for configuring the various unconfigured sensor devices. Accordingly, the command and control unit can determine which sensor devices will measure temperature, which will measure pressure, which will actuate valves and take air samples, or any other of the functions offered by the various sensor devices. Once the configuration data and  
30       commands are generated, the process 120 proceeds to step 124 wherein these data and

command signals are broadcast over the data network. In this step the data and commands are sent through the network to the transceivers, such as the transceivers 14 depicted in Figure 1 for broadcasting information to the various transceiver units 20 of the different integrated control devices 16.

5

After step 124 the process 120 proceeds to step 126 which is an optional step during which the command and control computer can ask for verification of the configuration. In this step, the command and control unit can determine that each of the integrated control devices received the command data sent to that device and properly  
10 configured and has operational the sensors and actuators that have been chosen by the command and control computer 12. If the initialization test fails, the command and control unit can optionally abort the initialization procedure and require user intervention, or take any other suitable steps.

15

In step 128 the command and control unit monitors data being collected by the various devices and transmitted back through the data network to the command and control computer 12. The command and control computer 12 can use this information for general process control and monitoring.

20

In the embodiment depicted in Figure 5, the process 120 has the optional step of proceeding to step 130 wherein the data returned from the sensor devices and actuators is monitored by the step 120 to determine if the process needs to be reconfigured for monitoring other characteristics of the system under control. If the system is to be reconfigured, the process 120 proceeds from step 130 to step 132 and generates and  
25 broadcasts new command and data signals that will reconfigure the sensor devices and actuator devices being employed by the command and control unit 12. Alternatively, if no configuration is necessary, the step 130 can proceed back to step 128 and begin to monitor data.

It will be understood that the embodiments of the invention which have been described are illustrative of some of the applications and principles of the present invention. Various modifications may be made by those skilled in the art without departing from the spirit and scope of the invention. Moreover, it will be understood that

5 the systems and devices described herein can be employed in a variety of applications including monitoring product moving along an assembly line, monitoring the activities of a vessel and any other suitable application.

I claim:

1. An apparatus for controlling a system, comprising  
a data interface for communicating data packages representative of data  
5 and commands signals across a data network,  
a communications manager, coupled to said data interface, for processing  
said data packages to exchange said data and command signals with a data processor,  
wherein each said data package organizes said data and command signals according to a  
predetermined format suitable for transfer across said data network, and  
10 a device manager adapted for processing said data and command signals  
to generate control signals for selectively configuring an operating characteristic of a  
device coupled to the system being controlled.
2. An apparatus according to claim 1, wherein said device includes a sensor coupled  
15 into communication with said device manager.
3. An apparatus according to claim 1, wherein said device includes an actuator  
coupled into communication with said device manager.
- 20 4. An apparatus according to claim 2, further comprising a housing containing said  
sensor, said device manager, said communications manager and said data interface.
5. An apparatus according to claim 3, further comprising a housing containing said  
25 actuator, said device manager, said communications manager and said data  
interface.
6. An apparatus according to claim 1, further comprising a multiplexed interface for  
allowing said device manager to monitor and control a plurality of devices  
coupled to the system being controlled.

30



7. An apparatus according to claim 1, further comprising an encryption processor for encrypting and decrypting said data and command signals transferred across the data network.
- 5 8. An apparatus according to claim 1, further comprising an interface for coupling to a system monitor to allow a user to monitor and adjust the operation of said device.
9. An apparatus according to claim 1, further comprising a system clock.
- 10 10. An integrated control device for monitoring characteristics of a system under control, comprising,  
a housing adapted for being removably and replaceably mounted to the system under control, said housing containing:  
15 a data interface for communicating data packages representative of data and commands signals across a data network and to a data processor,  
a communications manager, coupled to said data interface, for processing said data packages to exchange said data and command signals with said data processor, wherein each said data package organizes said data and command signals  
20 according to a predetermined format suitable for transfer across said data network,  
a device manager responsive to said data and command signals and being capable of controlling and monitoring a device,  
and  
a sensor for monitoring said characteristic of said system under control.
- 25 11. A semiconductor device for monitoring a system under control, comprising  
a substrate having a plurality of circuits formed thereon, said circuits  
30 including:  
a communications manager for processing data packages having data and command signals, wherein each said data package organizes said data and

command signals according to a predetermined format suitable for transfer across a data network,

5 a device manager adapted for processing said data and command signals to generate control signals for operating a device coupled to the system being controlled,

a sensor capable of monitoring a characteristic of the system under control, and

10 an actuator capable of adjusting an operating parameter of the system under control, whereby command signals communicated from a data processor are processed by said device manager for controlling said sensor and said actuator to perform selected operations.

12. An apparatus according to claim 11, wherein said sensor consists of a temperature sensor, a pressure sensor, an accelerometer, a gyroscope, a light detector, a microphone and any combination thereof.

13. An apparatus according to claim 11, wherein said actuator consists of a motor, a pump, a valve, a data port and any combination thereof.

14. An apparatus according to claim 11, wherein said communications manager includes an ID generator for generating data packets having a field for storing a system-under-control identification signal for identifying the system under control associated with said data packet.

15. An apparatus according to claim 11, wherein said communications manager includes an interface for communicating data packets to a physical layer device of the type suitable for communicating data over a data network.

16. An apparatus according to claim 11, wherein said communications manger includes an interface for communicating to a radio frequency device for

transmitting radio-frequency signals representative of the data and command signals.

17. An apparatus according to claim 11, wherein said communication manger includes  
5 an device id generator for generating a device ID signal for identifying the device generating the data packet.
18. A control system for monitoring and adjusting an operating state of a system under control, comprising  
10 a data processor of the type capable of processing information representative of at least one characteristic of an operating state of the system under control, and of generating command signals representative of instructions for configuring the operation of a sensor device, and  
a data network, coupled to said data processor and being of the type  
15 suitable for communicating information signals, and  
a plurality of said sensor devices, each being coupled to the system under control for monitoring a characteristic of the operating state of said system and each having  
a communications manager for processing data packages to  
20 exchange data and command signals with a remote data processor, wherein each said data package organizes said data and command signals according to a predetermined format,  
a device manager adapted for processing said data and command signals to generate control signals for operating a device coupled to the system being controlled, and  
25 a sensor capable of monitoring a characteristic of the system under control, whereby command signals communicated from said data processor are processed by said device manager for controlling said sensor to perform selected operations.

19. A control system according to claim 18, wherein said sensor device further includes an actuator device, coupled to said device manager and being capable of adjusting the operating state of the system under control.
- 5 20. A control system according to claim 19, wherein said data processor includes a mechanism for generating command signals for transmission to at least one of said plural actuator devices for configuring said actuator device to operate in a selected manner.
- 10 21. A process for controlling a system having an operating state and having at least one characteristic representative of the operating state, comprising
- 15 providing a data processor of the type capable of processing information representative of at least one characteristic of the operating state of the system under control, and of generating command signals representative of instructions for configuring the operation of a sensor device,
- providing a data network, coupled to said data processor and being of the type suitable for communicating information signals, and
- coupling a sensor device to the system under control for monitoring the characteristic of the operating state of said system, wherein the sensor has
- 20 a communications manager for processing data packages to exchange data and command signals with said data processor, wherein each said data package organizes said data and command signals according to a predetermined format,
- a sensor capable of monitoring a characteristic of the system under control, and
- 25 a device manager adapted for processing said data and command signals and for controlling operation of said sensor, and
- transmitting from said data processor command signals for configuring said sensor to operate in a selected manner.
- 30 22. A process according to claim 21, further comprising

providing an actuator capable of coupling to the system under control and  
adjusting the operating state of the system, and  
transmitting from said data processor command signals for directing the  
operation of said actuator.

5

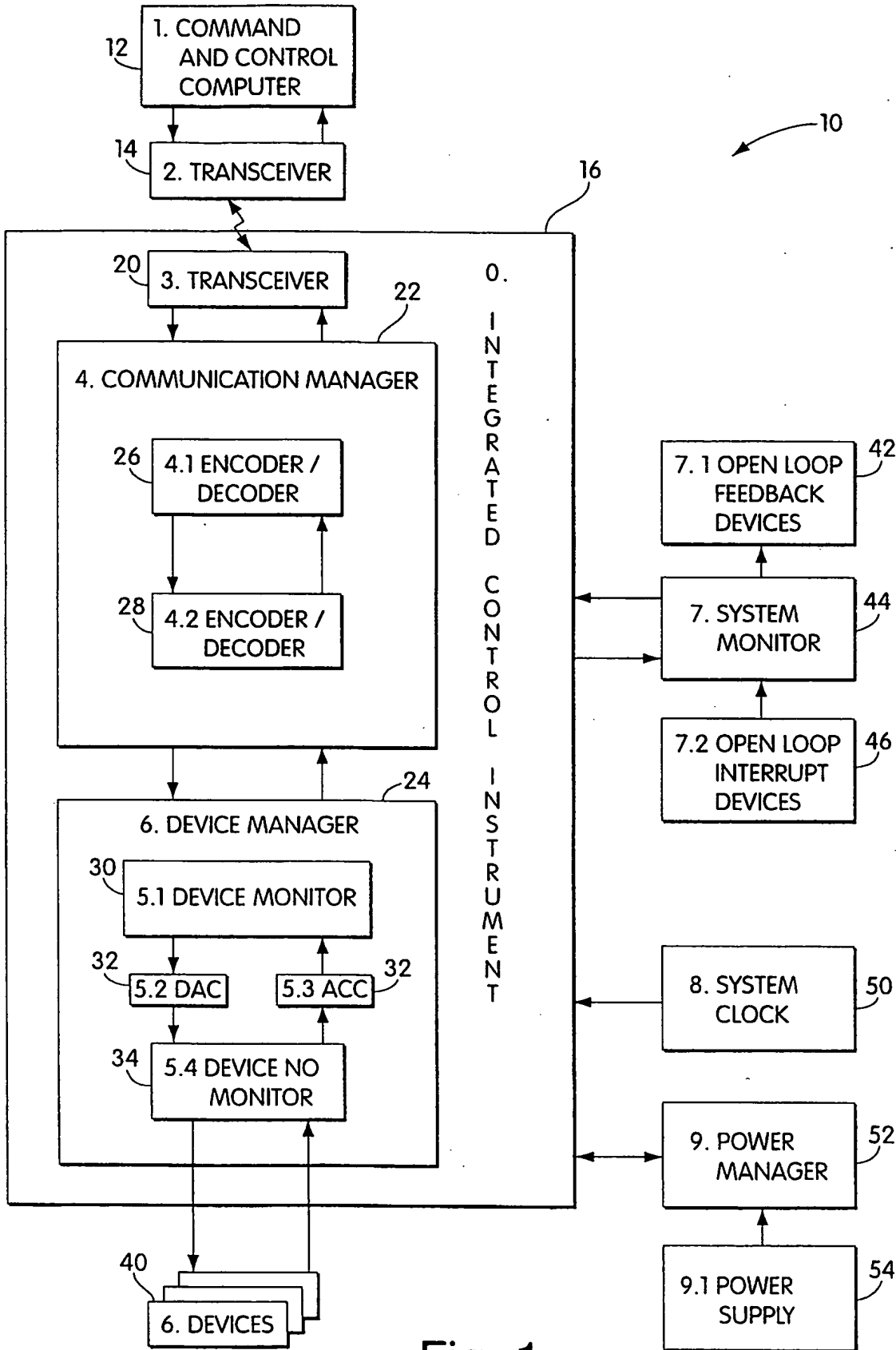


Fig. 1

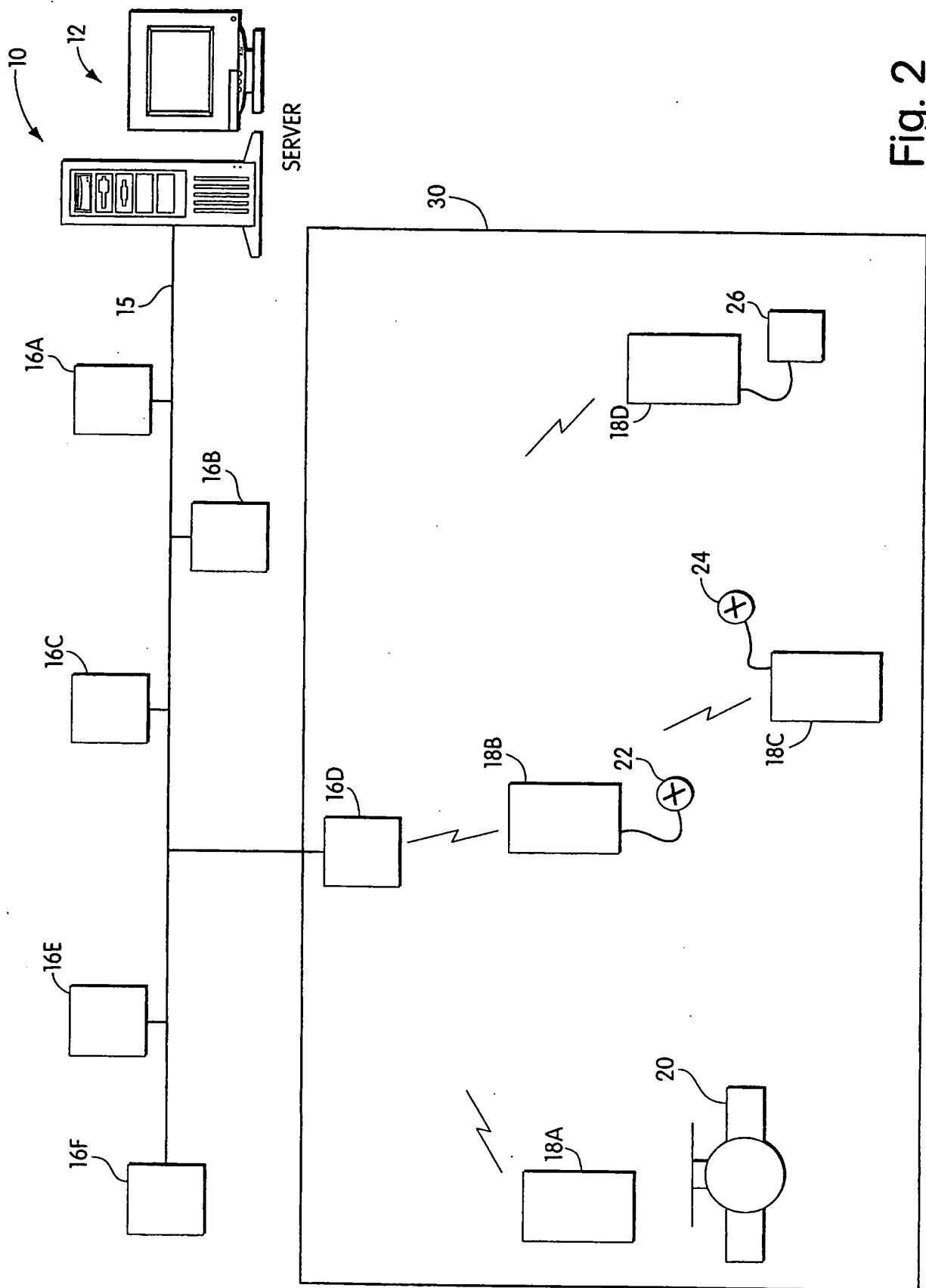


Fig. 2

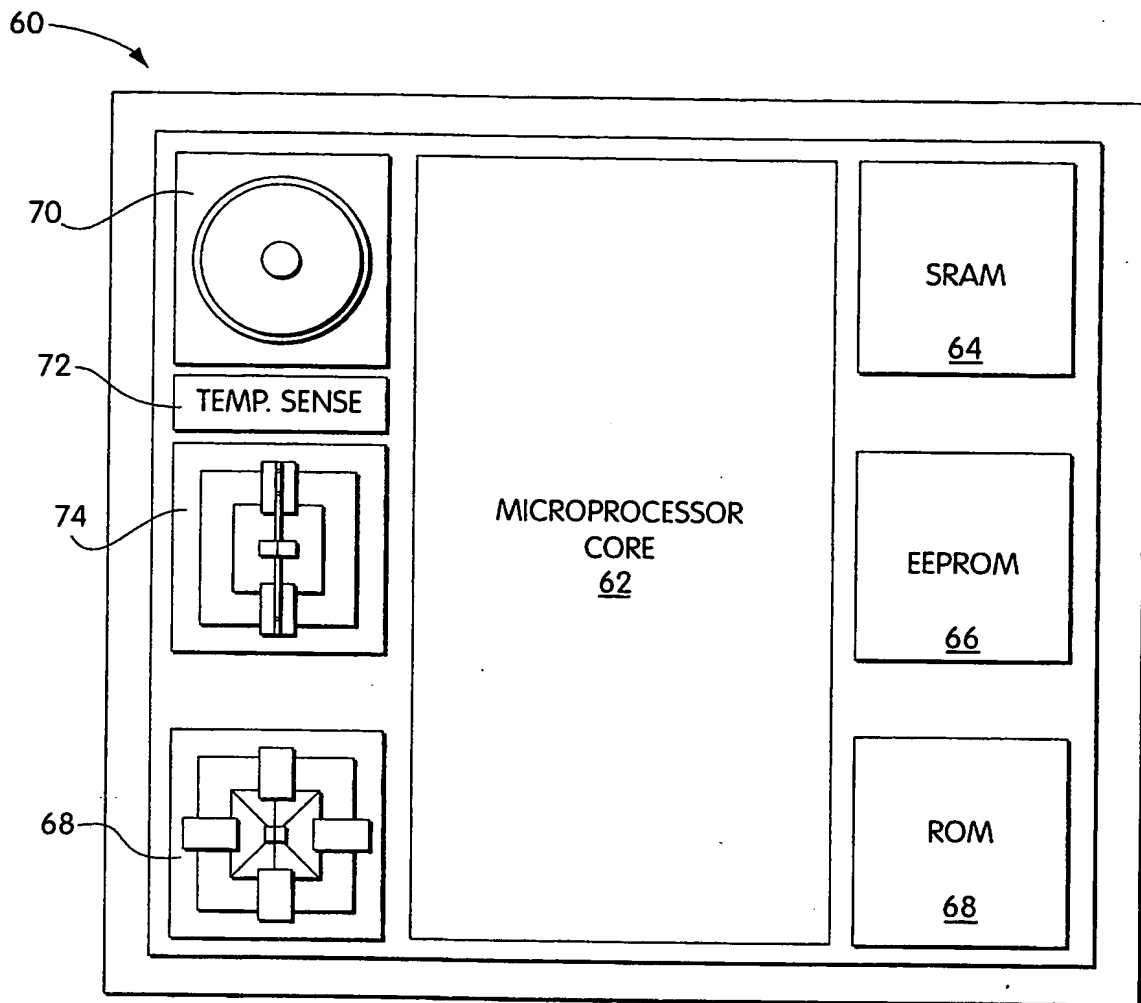


Fig. 3

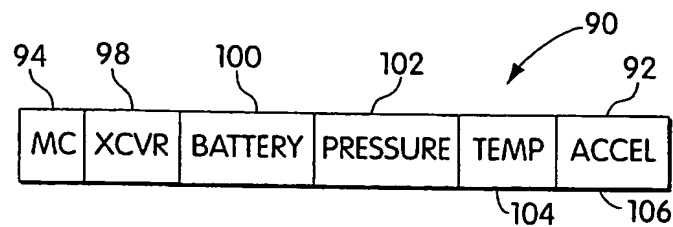


Fig. 4



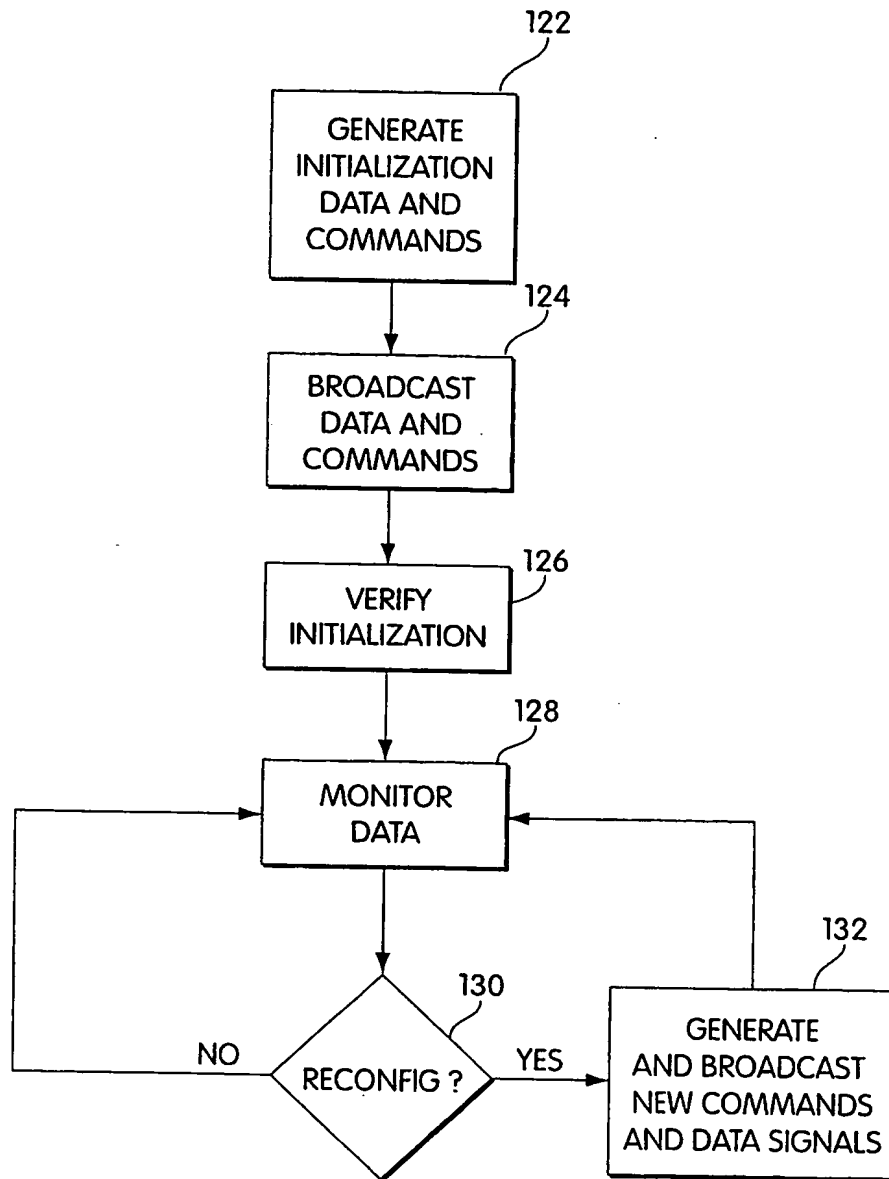


Fig. 5

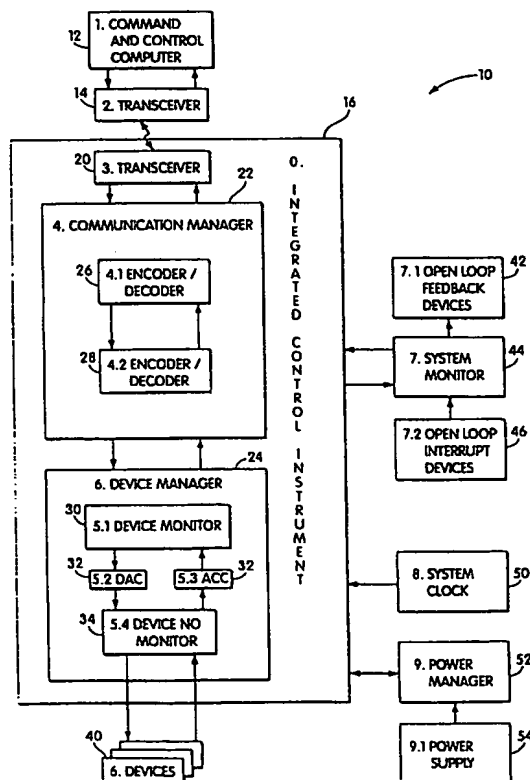


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US98/16490 <b>(22) International Filing Date:</b> 7 August 1998 (07.08.98) <b>(30) Priority Data:</b> 60/054,951                      7 August 1997 (07.08.97)                      US <b>(71)(72) Applicant and Inventor:</b> DE SCHRIJVER, Stefaan, A. [BE/US]; 952 Beacon Street, Newton, MA 02159 (US). <b>(74) Agents:</b> KELLY, Edward, J. et al.; Foley, Hoag & Eliot, LLP, One Post Office Square, Boston, MA 02109 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>  <b>(88) Date of publication of the international search report:</b> 29 April 1999 (29.04.99)

**(54) Title: MICRO-ELECTRO-MECHANICAL INTEGRATED CONTROL SYSTEMS****(57) Abstract**

An integrated electro-mechanical control device (16) has an interface (14) for communicating with a central computer system (12), or an array of computer systems, to allow for the distributed and reconfigurable development of a control network. The control units described herein can include a plurality of microelectronic devices (40) including micromachined sensors such as pressure sensors (102) and temperature sensors (90 and 104) which are formed on a chip including a circuit for being able to selectively configure the various sensor elements under the control of a central computing system.



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# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/16490

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US CL : 340/825.06; 370/340, 338, 462; 375/200; 379/88.22; 711/219

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 340/825.06; 370/340, 338, 462; 375/200; 711/219; 379/88.22

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

search terms: communication# mang?, data interface, monitor?, device manager#, encrypt?, sensor#

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,717,737 A ( DOVIK et al ) 10 February 1998 see entire document	1-10, and 18-22
X	US 4,734,909 A ( BENNETT et al ) 29 March 1998 see at least summary	11, and 14-17
X	US 5,553,220 A ( KEENE) 03 September 1996 see summary and figures 3, 8, and 9	12 and 13

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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